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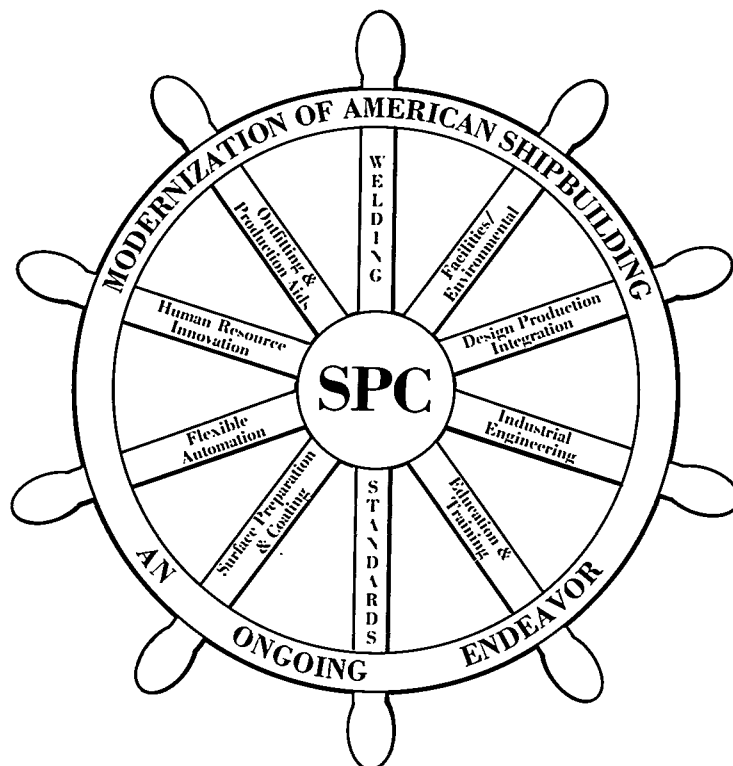U.S. DEPARTMENT OF THE NAVY
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1987 SHIP PRODUCTION
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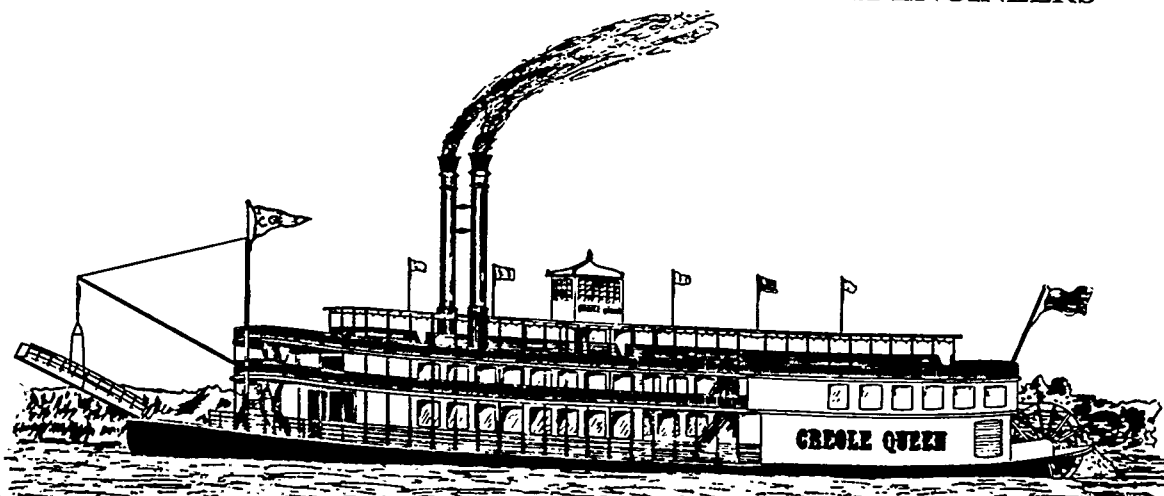
User's Perspective of CAD/CAM Software   No. 22

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ABSTRACT

Great emphasis has been attached to the achievement of productivity and producibility benefits through the application of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) technologies. To ensure the achievement of these benefits, it is important that the end user have appropriate software and is able to use it to his advantage. The proper procurement, customization, installation, training, and implementation of software can play a significant role in the effectiveness of CAD/CAM.

INTRODUCTION

Ingalls Shipbuilding Division has made major commitments to the use of computer software to assist design and manufacturing functions. A quarter-century of experience has been compiled in the use of batch stand-alone systems to aid the engineer in the computational aspects of his job. The first major integrated manufacturing effort began in 1968 with the acquisition and installation of a system to take in design definition data, perform some of the naval architectural functions, and ultimately produce the numerical control instruction sets needed to programmatically direct the cutting of structural steel plate.

In February 1979, Ingalls took delivery of the first software and hardware specifically intended to assist the designer with the labor intensive drafting activity. Four years later, it was recognized that in order to gain the maximum benefits from this data, product definition would have to be more complete and representation in a three-dimensional coordinate system would have to be accompanied by the attribute data that gives meaning to a model. This is to say, the model members must be identified not only by their dimensional properties, but also by material, specification, source identification and other information that would allow the model data to ultimately be integrated into the downstream design, planning and manufacturing areas.

As a result of these milestones being accomplished, Ingalls presently finds itself with a capability of integrated hardware and software that includes a quadraplex of mainframes, thirteen graphic workstations used exclusively for drafting purposes, and self-contained workstations operating in a ring-network (see Figure 1) being used for the creation of three dimensional (3-D) design models, drawings, and associated manufacturing aids. This gives Ingalls a state-of-the-art design capability.

These achievements were not gained without pain. False starts, misconceptions of abilities (of both man and machine), and overly ambitious plans have been experienced enough times to make them completely unpatentable. The remainder of this paper will share some of our findings in hopes that you will profit from our mistakes and take advantage of our successes.

THE TURNKEY SYSTEM

Many CAD systems are available on the market today and most profess to be turnkey. That is, they present themselves as a ready solution to your problems, which can be immediately implemented and used with neither waiting nor modification required. Beware!

It has been our experience at Ingalls that no system is available today that will do our job completely. Nor will it do it the way we want it done. Therefore, it becomes immediately obvious that certain provisions must be accepted with the selection of any turnkey system.

The system, as selected, will serve as a baseline for future development and expansion. The system will often require software modification to suite existing company methods and procedures. This is preferable to changing the company to suit the software.
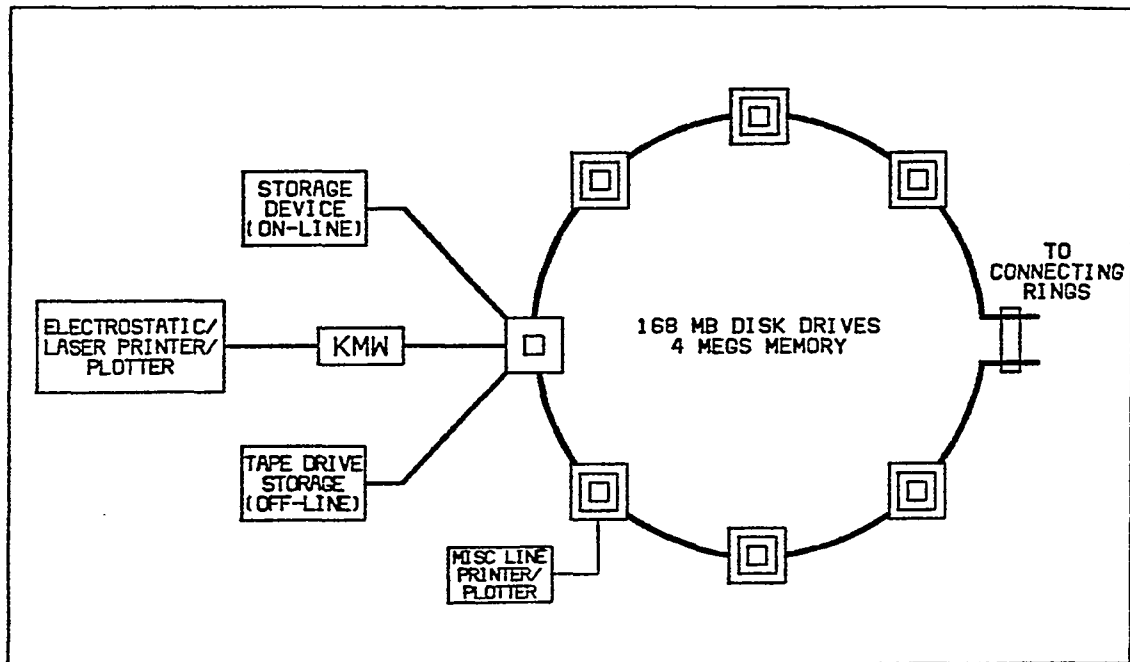
FIGURE 1 - TYPICAL CAD RING/NETWORK CONFIGURATION

No software is ever tested to the extent that it can envision all of the possible uses that creative users can imagine. And when software fails, someone will have to support the shortcoming.

And certainly, a major provision to be made concerns funding. Regardless of whether you intend to provide all software support internally, hire someone to do it, or some combination of the two, it will take time and it will cost money. Support of your schedules and conformance to your priorities should be the major considerations, because it will be done with your money. So much for the turnkey myth.

THE SOFTWARE TREATMENT ALTERNATIVES

In spite of the notes of negativism regarding the infallability and incompleteness of vendor offerings, one should not assume that a system that is not perfect has no value. I submit that a more practical and realistic position is to view the procured system as a software baseline, or foundation if you prefer, rather than the solution to all of your problems. This perspective offers you several alternatives. The application and prioritization of these alternatives may vary or be interchanged as situations and circumstances dictate.

Alternative 1 - Use the System as Procured and Accept Its Limitations. In spite of the system's shortcomings, often you will still be provided tools

that are preferable to manual methods. The pressure of schedule and the limitation of time, money, and development resources make this option viable for short term solutions.

Alternative 2 - Enter Into an Agreement With Your Supplier to Provide a Fixed Amount of Development Resources. This agreement will be used to custom tailor his basic software offerings to your specifications. This allows the author of the code to use his expertise, minimizes the programmer learning period, and results in a more capable product. At the same time, the vendor is benefiting by having a more marketable product, an in-use computer base, and a development cost being defrayed by your participation.

Alternative 3 - Hire Outside Independent Software Developers. In spite of the promises these people normally make, they usually face the same basic problems that you do -- learning curves, etc. -- with the added problems of understanding neither your requirements nor the vendor's offerings in any level of detail. There are some companies that specialize in software for selected CAD systems, but this option can usually be dismissed out of hand unless the task is very well defined.

Alternative 4 - Acquire an Internal Development Capability. While this alternative usually appeals to one's basic desire to be an innovator, it must be recognized that the cost involved

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with training, managing and retaining a qualified staff capable of quality and timely software development of this specialized nature must never be underestimated.

IMPACTS OF ALTERNATIVE SELECTION

As previously mentioned, the use of a system with serious shortcomings may be workable on a temporary basis, but over time one can expect adverse effects. User enthusiasm and commitment to the system's success -- the two most important ingredients required -- will suffer. Software inefficiency and workarounds will also bring about procedural and management problems.

The use of outside software developers takes daily project oversight away from in-house control and tends to retard software integration. And by placing total reliance for support outside your company, you are also forfeiting any opportunity to gain a full and complete understanding of the capability of the system.

As a final word of caution, projects involving software systems of this size are usually very complex and expensive. The specification development becomes the primary tool for performance measurement and requires an inordinate amount of detail in order to assure that the system will satisfy all of your needs.

INGALLS ALTERNATIVES EXPERIENCE

At times, on different software projects, Ingalls has made use of all of the alternatives discussed. However, on the CAD/CAM project, the focus has been on combining the creation of an internal staff with the use of dedicated resources from the system vendor. These arrangements were part of the original procurement negotiations, which assisted in the forming of favorable terms, conditions, and rates. By combining these two techniques, Ingalls has used its vendor's experienced personnel as hands-on trainers and, at the same time, has made the Ingalls technical personnel more familiar with the proven techniques for development and testing that might not have been covered in a classroom environment with instruction by a professional trainer. This has also aided in the solution of continuity-of-personnel problems. With a small staff of people at the two facilities interfacing with each other, there has been less likelihood of an individual becoming the single expert in any field. Therefore, in instances where people have been lost through normal attrition, the impact on schedules and other commitments has been lessened. This approach has been successful at Ingalls, and I would encourage anyone considering entry into the CAD/CAM world to consider it.

TYPES OF SOFTWARE ISSUES

Acquisition and installation of CAD/CAM systems will present opportunities to deal with different types of software issues. One of these is system oriented software. The software's ability to allow orderly installation and testing of changes and/or new releases of operating systems in an orderly fashion is not unlike its counterpart requirement for mainframes in a general data processing shop. Also, one must recognize the need for management system concerns, such as workstation availability, workstation usage, data security, and database management. Let me point out now that no single CAD/CAM vendor, to my knowledge, has satisfactorily developed his offering to the point of adequately satisfying the requirements of the user community for all of these needs. Because of these shortcomings, it has been necessary for Ingalls to direct significant resources toward the development of such tools. This has not changed our view that this most lacking area of software capability is one of the most important.

Communication software, linking workstations to each other and to mainframes, should be considered by any potential user. Only recently have we been able to satisfactorily achieve a reliable communication link between the mainframe processors and all of the ringed workstations located throughout the shipyard. This experience provides an excellent example of dealing with software "futures". While it will always be true that there is a certain amount of risk involved in the acquisition of software, you are cautioned to assure yourself that enough of your mandatory system attributes are clearly specified so that meaningful and cost justified work efforts can take place upon system acceptance while these "futures" are still being developed and tested.

APPLICATION ISSUES

Application software is, without question, the paramount issue involved in the selection of a CAD system. Targets for application software functionality are cited in Figure 2. This is the issue that will produce the product, thereby determining the cost effectiveness of the system's usage. At Ingalls, design areas are specialized by discipline and customized software has been developed for each of them to make the user/software interface as efficient as possible.

These design disciplines are:

1.   Structure
2.   Heating, Ventilation, and Air Conditioning
3.   Electrical

STAGE 1	STAGE 2	STAGE 3
FUNCTIONAL DESIGN	TRANSITION DESIGN	WORKING INSTRUCTIONS
SPECIFICATIONS REVIEW	GRAND BLOCK/BLOCK MODEL BREAKDOWN	DEVELOP STRUCTURAL FABRICATION PACKAGE
SCANTLING CALCULATIONS & PREPARATIONS	MERGE FINAL STRUCTURE	DEVELOP STRUCTURAL INSTALLATION PACKAGE
LINE FAIRING	DEVELOP CONNECTING STRUCTURE & FOUNDATIONS	DEVELOP FINAL FABRICATION PACKAGE
C & A DEVELOPMENT (PRELIMINARY)	DEVELOP FINAL EQUIPMENT	DEVELOP FINAL MACHINERY PACKAGE
KEY SPACE ARRANGEMENT	DEVELOP DISTRIBUTIVE SYSTEMS	DEVELOP FINAL INSTALLATION PACKAGE
SYSTEM CALCULATIONS & DIAGRAMS	FINALIZE MACHINERY PACKAGES	
FINITE ELEMENT ANALYSIS	PENETRATIONS	
DISTRIBUTIVE SYSTEMS ROUTING	INTERFERENCE CHECK	
WELDING PLAN & STANDARD DETAILS	FINALIZE TOTAL DESIGN	
MACHINERY PACKAGES TECHNICAL & PRELIMINARY DATA	ADVANCE BILL OF MATERIALS	
ADVANCE BILL OF MATERIALS	JOS & BACKUP STRUCTURE	
INTERFERENCE CHECK		

FIGURE 2 - APPLICATION SOFTWARE FUNCTIONS

4. Combat Systems Integration
5. Piping and Machinery

Although the product and the design techniques differ for each of these disciplines, software products for all of them have been developed using a common philosophy. And that is that the primary software product will be the 3-D design model. Figures 3 and 4 are examples of some of these models, and how they appear as created by the designer.
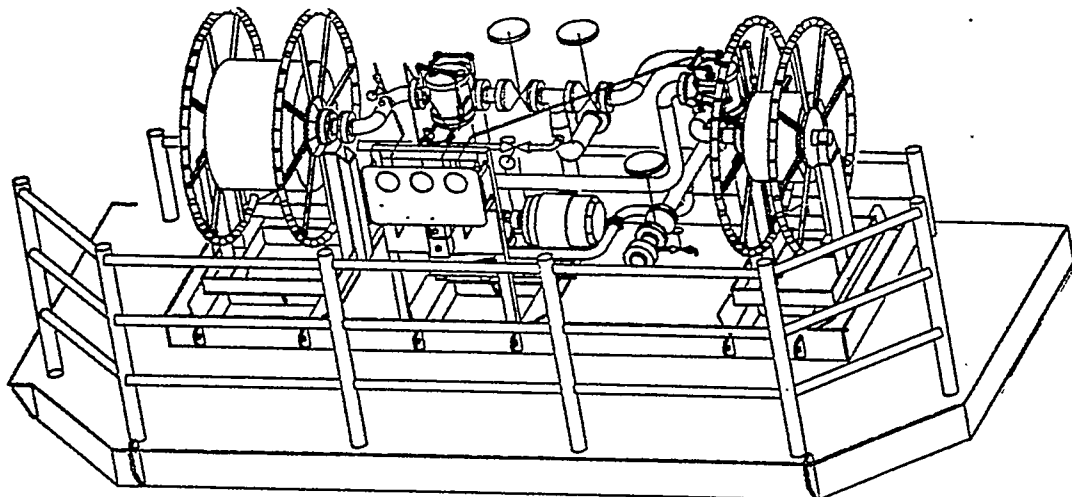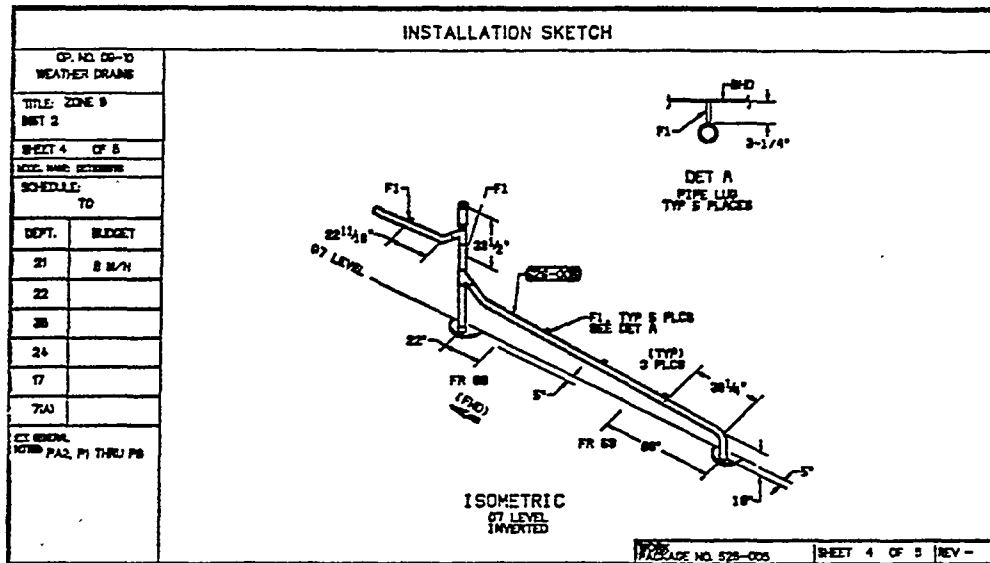

FIGURE 3 - TYPICAL 3-D MODEL

FIGURE 4 - TYPICAL 3-D MODEL (EXPLODED)

The special application software that has been developed for Ingalls has been designed to be totally external to the vendor's base product. The vehicle used for this development has been a language supplied by the vendor and intended exclusively for interfacing with the primary application routines. We have found that the vast majority of CAD systems have been developed to service the electronics industry, for printed circuit board design, or the petrochemical, aerospace, and automobile industries. Some similarities do exist between these industries and shipbuilding, but more often than not, we found that basic shipbuilding practices required capabilities not needed by our friends in the oil refineries. The reasons for these differences are readily understandable when we picture the contrasts in the design environment for space alone. Since much of the piping in the petrochemical industry is very large and located in an open area, general design practices tend to have very long runs of straight pipe and a high usage of standard fittings (usually 90 degrees). The limited space available in the ship's hull is occupied not only by the counterpart piping systems, but by the other design disciplines' products as well. This re-

sults in the need for higher incidents of direction changes and increased use of bent pipe as opposed to using fittings. The use of pipe bending not only reduces pipe fitting time and welding, but reduced weight, which is still another environmental difference.

Application software has also been developed to add rules for producibility to the design process. Sample piping product outputs are shown in Figures 5 and 6. Lengths of straight pipe between bends are validated against the pipe bending machine's capabilities, to ensure sufficient clamping room exists. Bend angles are verified against pipe lengths to make certain that the pipe extending from the machine will not contact the shop floor during bending. Other rules are continuing to be added as the need for them is identified, thus pointing out that the software expansion criteria is an ongoing concern.

The modeling concept has given the shipyard new tools which allow functions to be automated to a degree never before practical. Individual discipline models are merged in a master model which is then interference checked to prove that no component exists in the same space as another element. Savings from this

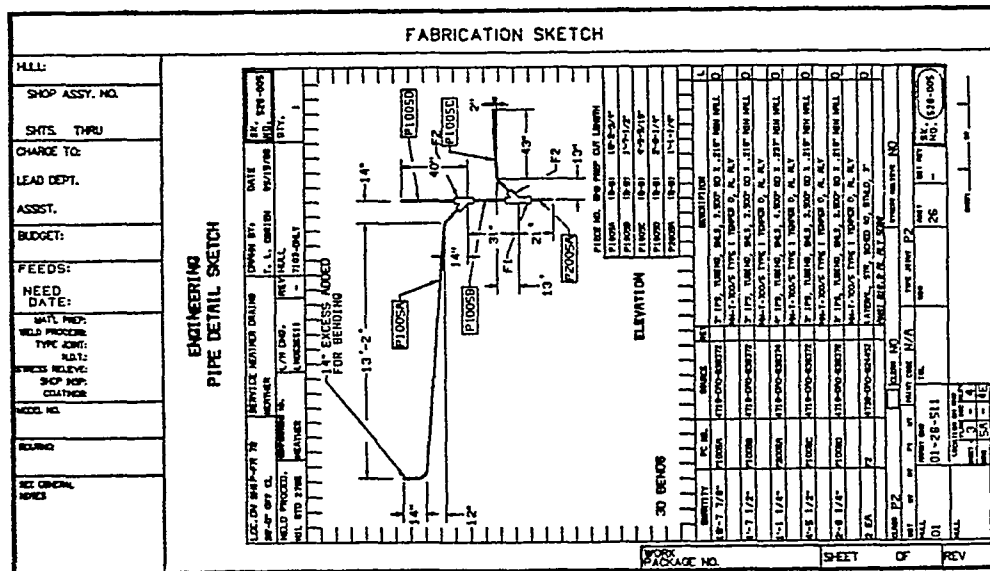**FIGURE 5 - TYPICAL PIPING MANUFACTURING DETAIL**

FIGURE 6 - TYPICAL PIPING INSTALLATION DETAIL

process alone may ultimately return the entire original investment when all design data is available in model form.

THE CAM IN CAD/CAM

The term CAD/CAM may be the industry catch phrase, but in most installations, the CAM part of the acronym mysteriously disappears. The main reason for the absence of CAM from most systems is simple; it never existed in the first place. Again, most of the system development in the CAD/CAM industry was pointed at a very narrow market segment.

This led to systems that could do any form of manufacturing support you wanted, as long as it was done in APT.

Since only a very small portion of the computer aided manufacturing support at Ingalls involves machines which require APT generated instruction sets, it became incumbent on us to develop interfaces for numerically controlled machines in different manufacturing shops, many of which require different data structures and instruction sets. Pipe, sheet metal, plate steel and aluminum are all produced through the

use of numerically controlled equipment. Because of the software facilities available to us, Ingalls has and is continuing to create manufacturing support interfaces that not only interface with data created in the design process, but do it in a fashion that eliminates much of the physical paper communication media which has existed for years.

The state of the integrated software art in CAM is significantly behind its CAD predecessor because of the priorities in software development. This is probably the correct order of precedence since without the data being generated as an integral design function, the cost of acquisition for manufacturing support alone distorts the true cost effectiveness. However, in the shipbuilding industry, CAM is where the money is!

THE SOFTWARE SEQUENCE

The correct sequence of events to assure success is sometimes misunderstood or misapplied. A suggested guide for software inclusions in a CAD/CAM system are included for your information and use.

1. The RFP and Specification – The most important elements in the process. Take the time and spend the effort to insure that the software you buy will do the job -- the way you want it done.

2. Benchmark and Evaluation – This is the first opportunity available to rule out gross shortcomings of capability and to determine the efficiency of the software as well as its functionality. Efficiency should not only include timings of performance, but should consider things such as complexity and ease of use.

3. Installation and Acceptance – These issues are particularly critical because they provide the last major levers at your disposal to get everything you're paying for in the basic system procurement. Once acceptance is established, the next software activity is likely to cost you additional money.

4. Training and Usage – Be certain that your implementation plan not only provides for training for applications software, but for all other types of software as well. The need for system management, system support, and error detection and correction

software must be recognized and dealt with as an integral part of installation -- not as an afterthought.

5. Maintenance and Updates – Establish a firm vehicle to communicate with your supplier all forms of problems. Determine not only how to report them, but how to classify them with respect to responsibility for action, priority, and expected resolution time.

Understand the impact of such items as new software releases with regard to ongoing work commitments and the requirement on your part to properly install and test it prior to making it available to the user, who cares less about software, except when it fails.

THE CAD/CAM SOFTWARE FUTURE AT INGALLS

Software development and procurement at Ingalls will proceed at the rate of, and in conjunction with, the quantities and types of ships that comprise our business base. In the event that we are successful in acquiring work requiring a high incidence of design activity, major emphasis will be placed on improving the cost effectiveness of the workstation/user interface in order to gain more correct and more complete data from which downstream functions can gain.

However, if contracts are primarily of a construction nature utilizing designs which have previously been done by Ingalls or by another lead yard, the obvious need is to develop means by which existing data can be more effective in planning and in operational tasks.

Ingalls will continue to place high emphasis on software that deals with database management and communications. We realize that our experience to date is still extremely limited when compared to the task we see before us and data and configuration management features will require much improvement before we can consider them adequate.

We will continue to try to influence vendors, both our primary vendor and the industry in general, to develop software that can be somewhat generic in nature. We will work with the Navy, software suppliers, and the National Bureau of Standards on the future development of the Initial Graphics Exchange Specification (IGES) and its expected successor, Product Data Exchange Specification (PDES).

We hope that this information relates to your problems and plans and that it serves to provide a means to avoid some of the pitfalls inherent in the acquisition of the heart of any CAD/CAM system — software.

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